NASA Facts

National Aeronautics and
Space Administration

Marshall Space Flight Center
Huntsville, Alabama 35812

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Infinite Journeys

In-Space Propulsion Technologies Opening the Frontiers of Space

"The 21st Century will see the planets drawn together and the complexion of human civilization changed. Space has already demonstrated that a bountiful future is not possible for mankind without it."
– Krafft A. Ehricke, *Men Of Space*

Imagine driving all the way from an East Coast city to the Grand Canyon in Arizona — one of the most breathtaking natural spectacles in the world. Then imagine simply driving by without slowing down, snapping as many photos as possible as it blurs past.

That 's a rough equivalent of the way many past missions to the outer planets — Jupiter, Saturn, Uranus and Neptune — have been conducted.

Typically, fuel loads make up half the weight of any interplanetary spacecraft. Conventional chemical propulsion systems send these probes millions of miles across the solar system, trying to get as close as they can to a planet in order to capture as much information as possible. But the lack of fuel available for orbital braking and maneuvering often means the probes must fly right by each planet — or remain stuck in a limited orbit until they fall to destruction.

While humankind has learned a great deal from past visits to the outer planets — Pioneer 10 and 11, the "Grand Tours" of Voyager 1 and 2, and the Galileo mission to Jupiter — those trips have merely tantalized us with the promise of knowledge and possibilities yet to be revealed.

Jupiter

Distance from Earth
390.6 million miles
(628.7 million kilometers)

Temperature
Interior temps may reach 35,000 degrees Fahrenheit
(19,400 degrees Celsius)

Atmosphere
90 percent normal and liquid metallic hydrogen, 10 percent helium, with traces of methane, water and ammonia

Geology
Gaseous materials densify to an inner core 10-15 times the size of Earth

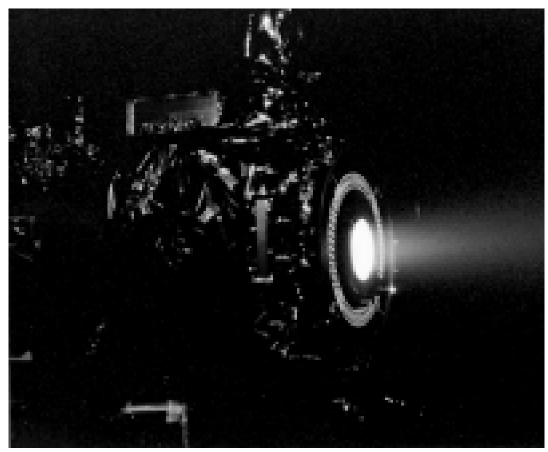
Moons
16 confirmed, 12 unconfirmed

Rings
A single, faint ring similar to Saturn's in composition

NASA is now seeking new means of enabling faster and more capable missions into the outer planets — ones that will permit more detailed, long-term studies of the planets, their myraid moons and other bodies in the solar system.

At the forefront of this effort is research now being conducted by NASA's In-Space Propulsion Program, managed by the Office of Space Science in Washington, D.C., and implemented for NASA by the Marshall Space Flight Center in Huntsville, Ala. The In-Space Propulsion program is also supported by Ames Research Center in Moffett Field, Calif.; Glenn Research Center in Cleveland, Ohio; the Jet Propulsion Laboratory in Pasadena, Calif.; Johnson Space Center in Houston, Texas; and Langley Research Center in Hampton, Va. NASA also partners with government, industry and academic organizations around the nation to pursue its in-space propulsion goals.

Solar Electric Propulsion

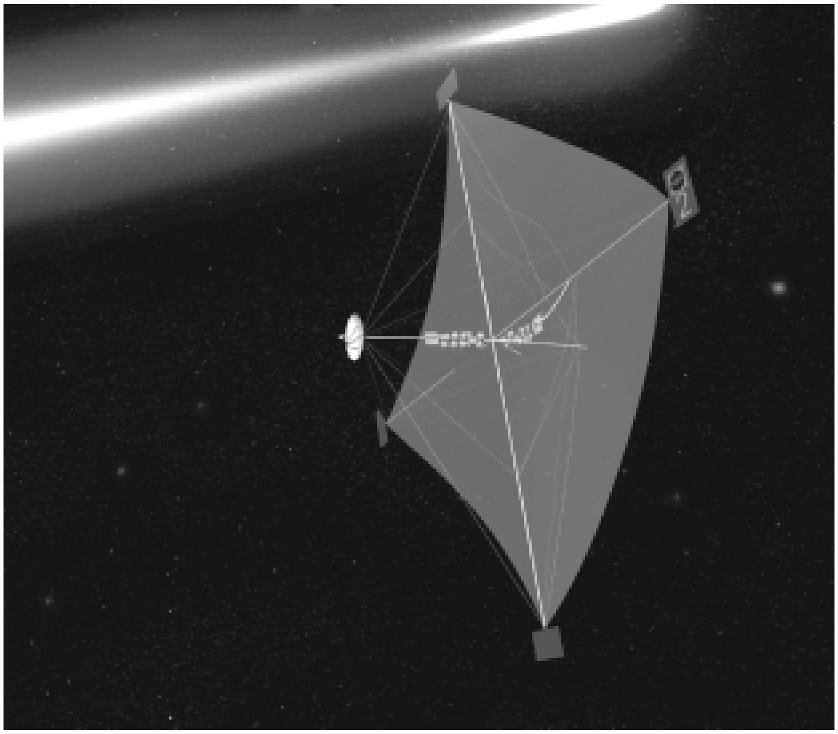


Test firing the Deep Space 1 ion propulsion engine

Solar electric propulsion technologies use electrical energy derived from the Sun to accelerate a propellant, which is then converted to kinetic energy, or thrust. This lightweight alternative to heavy chemical propellant enables electric-propulsion vehicles to travel faster, carry larger payloads and accomplish broader mission objectives, unhampered by the weight and expense imposed by conventional chemical propulsion.

One solar electric technology now in use by NASA is ion propulsion, which boasts 10 times the fuel efficiency of an on-board chemical propulsion system. An ion engine powered NASA's successful Deep Space 1 mission, which was launched in October 1998 and retired in December 2001. Deep Space 1 has given NASA researchers new insight regarding in-space propulsion requirements — and made scientific history in September 2001 during its flyby exploration of comet Borrelly.

Back on Earth, a twin of the xenon-fueled ion engine powering Deep Space 1 has surpassed all expectations during ground life testing. By May 2002, the engine had operated continuously for more than 23,000 hours — 220 percent of its expected life, and the longest any rocket engine has ever sustained operation.



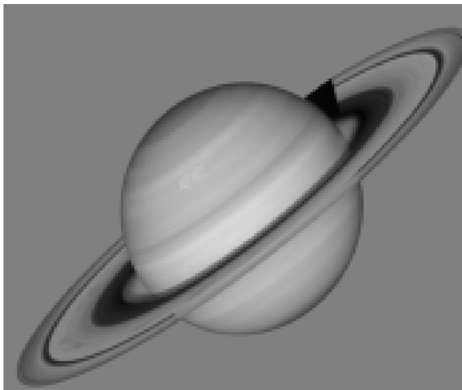
An artist's concept of a space sail in flight

In the future, NASA expects solar electric propulsion engines to become leading candidates for propelling missions to Europa and other Jovian moons, and to the other outer planets. Research into lightweight and even more efficient ion propulsion system components and subsystems is now underway.

Solar Sails

Solar sail technologies offer additional means of sending vehicles to any point in the solar system. Sunlight could push a solar sail to tremendous speeds — much faster than today's propulsion systems. And because the Sun supplies the necessary propulsive energy, solar sails need no on-board propellant.

The chief advantage of the solar sail is its unique capability to accomplish scientific endeavors in the inner solar system. NASA is now proposing a number of missions to study the "Sun-Earth Connection," our planet's relationship with its parent star and the turbulent space weather it creates. Because some missions would call for the craft to hover in space, rather than orbit Earth or the Sun, the vehicle would need a constant propulsion source to hold its position. Conventional chemical power or even very efficient electric propulsion systems would require too much fuel to sustain such a mission. A solar sail would be ideal, revealing the Sun's violent secrets and providing early warning of large-scale geomagnetic storms that might threaten Earth satellites, communications systems and power grids.



Saturn

Distance from Earth
795.2 million miles
(1.27 billion kilometers)

Temperature
Interior temps reach 21,000 degrees Fahrenheit (11,600 degrees Celsius)

Atmosphere
Approximately 75 percent hydrogen and 25 percent helium, with traces of water, methane and ammonia

Geology
Gaseous surface above liquid-metallic hydrogen layers, molecular hydrogen layers and a rocky core

Moons
18 confirmed, 12 unconfirmed

Rings
Trademark rings are composed of water ice and icy rock particles

Uranus

Distance from Earth
1.69 billion miles
(2.72 billion kilometers)

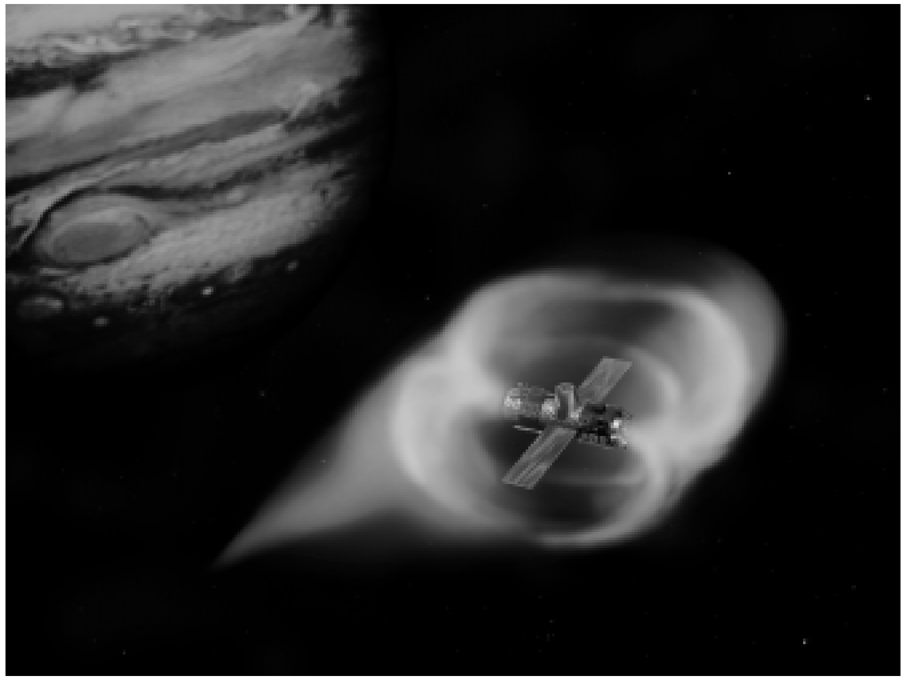
Temperature
-350 degrees Fahrenheit
(-212 degrees Celsius)

Atmosphere
83 percent hydrogen, 15 percent helium, 2 percent methane

Geology
Primarily rock and ice; helium/hydrogen core

Moons
21

Rings
11 faint rings



An artist's rendering of a plasma sail vehicle as it nears Jupiter

Plasma Sails

Another promising sail concept now being developed is the plasma sail — a huge, magnetic bubble generated aboard a small interplanetary vehicle and pushed along by charged particles of the solar winds, which travel at speeds upward of 100,000 miles per hour. Plasma sail technologies — nearly weightless and benefiting from an inexhaustible propulsion source — could cut conventional trip times to the outer planets in half, benefiting research missions and perhaps one day serving as a means of resupplying vehicles parked in permanent orbit around other worlds.

Tether Propulsion

NASA is developing experiments to show that tether-based propulsion — a propellant-free technology that draws power from a planet's atmosphere and rotational force — could raise and maintain the orbits of other spacecraft, including communications satellites and probes destined for the outer planets of our solar system. Tether technology uses the scientific principle of "momentum exchange" — the action of transferring momentum from one body to another. By briefly linking a slow-moving object with a faster one, the slower object's speed may be dramatically increased as some of its counterpart's momentum is transferred to it.

A self-stabilizing tether-based propulsion system could be working in Earth orbit in 10-15 years, raising and lowering satellites. Eventually, the technology is expected to enable cheap, efficient transport of payloads beyond low-Earth orbit — paving the way for a return to the Moon, as well as journeys to Mars and the outer planets.

Aerocapture

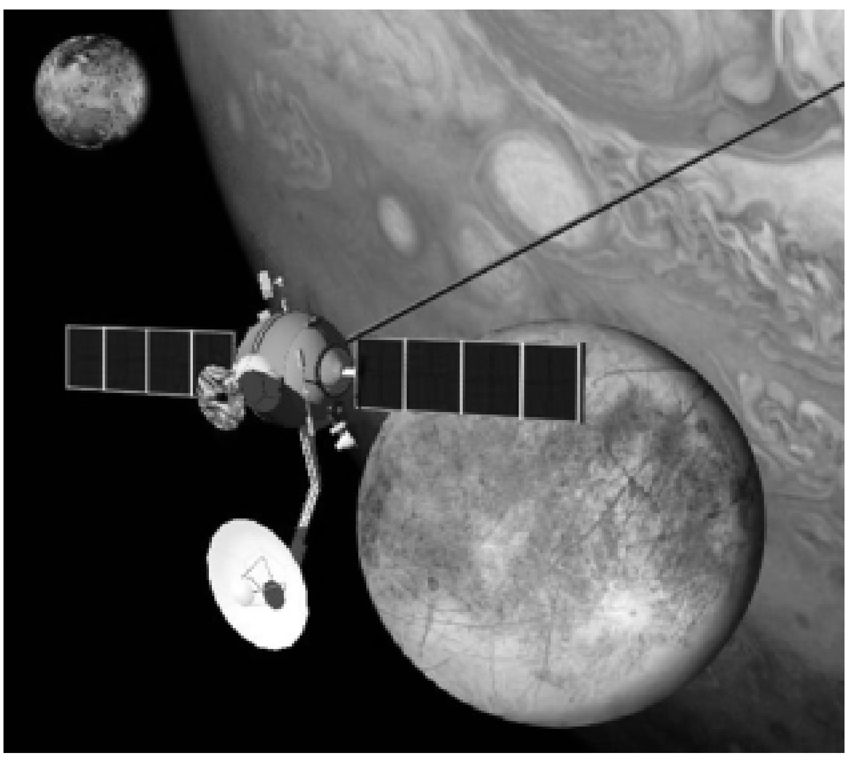
Aerocapture — the use of a planet's atmosphere to slow down a spacecraft — is part of a unique family of "aeroassist" technologies that will enable missions to the most distant planets in our solar system. An aerocapture vehicle approaching a planet on a hyperbolic trajectory is "captured" into orbit as it passes through the atmosphere, without the use of on-board propulsion. This fuel-free method could reduce the typical mass of an interplanetary spacecraft by half, allowing for a smaller, cheaper vehicle — one better equipped to conduct robust, long-term science at its destination.

A Revolutionary Paradigm Shift

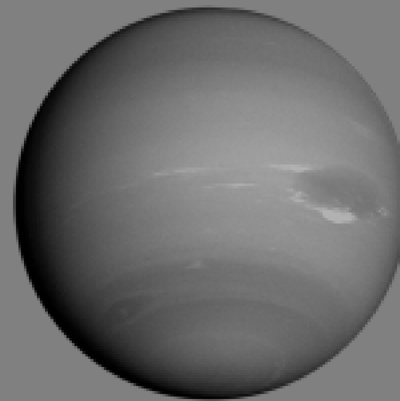
All these technologies represent NASA's efforts to decrease trip times and reduce the weight of propulsion systems required for outer planet missions, enabling us to routinely send robust, long-duration probes and survey craft to the outer solar system, and paving the way for eventual human exploration of our neighboring worlds.

The efforts of the In-Space Propulsion Program to develop advanced propulsion systems will revolutionize NASA's interplanetary mission paradigm, allowing us to pick the right technology to match any proposed outer-planet mission, rather than developing missions that fit — and are limited by — the narrow parameters of existing technologies.

No longer can we focus on trying merely to get from Point A to Point B. Today, NASA seeks propulsion technologies enabling us to reach *all* points — quickly, safely and with a maximum return on investmentt — throughout our solar system and beyond.



Artist's rendering of a tether-based propulsion system in operation in the Jovian system



Neptune

Distance from Earth
2.71 billion miles
(4.35 billion kilometers)

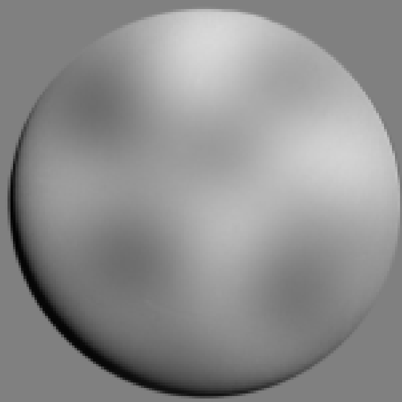
Temperature
-350 degrees Fahrenheit
(-212 degrees Celsius)

Atmosphere
Hydrogen, helium and methane levels similar to Uranus; fastest atmospheric winds in the solar system, exceeding 1,500 mph (2,414 kilometers per hour)

Geology
Gaseous outer surface; core of rock, ice and liquid hydrogen

Moons
8

Rings
Four faint, dark rings



Pluto

Distance from Earth
3.58 billion miles

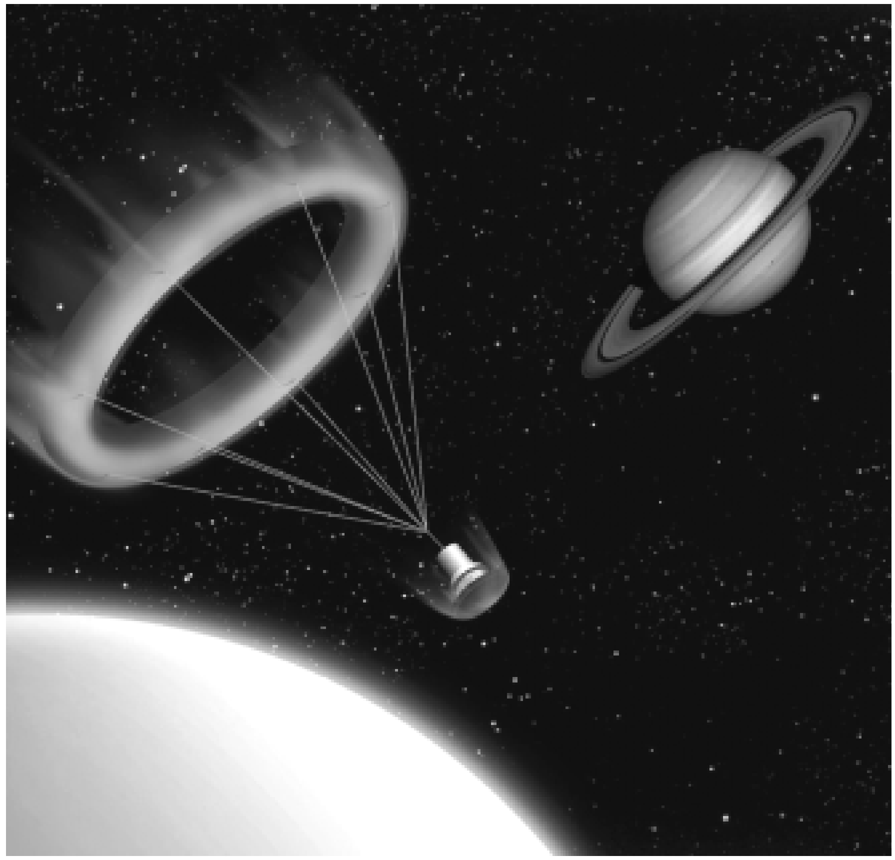
Temperature
-373 degrees Fahrenheit

Atmosphere
Indications of heavy nitrogen, with some carbon monoxide and methane; entire atmosphere may freeze solid except when closest to Sun

Geology
Studies suggest 70 percent rock, 30 percent water ice containing nitrogen, methane, ethane and carbon monoxide

Moons
1 (Charon)

Note
Note: For 20 years out of every 240, Pluto's orbit brings it closer to the Sun than Neptune. This phenomenon last occurred between February 1979 and February 1999. It will start again in 2219.



An artist's concept of an aerocapture system: a toroidal "ballute" deploying at Saturn's moon Titan

About the In-Space Propulsion Program

The coming generation of scientific exploration missions presents NASA with unique challenges. Chief among these: fast access throughout the solar system and the ability to rendezvous with, orbit and conduct *in situ* exploration of planets, satellites and small bodies. It is the mission of the In-Space Propulsion Program to develop propulsion technologies that will benefit future NASA science missions by significantly reducing travel times required for transit to distant bodies; increasing their capability by reducing the mass of the propulsion system; and enabling new destinations and new vantage points for science.

For more information about NASA Space Transportation Systems and the In-Space Propulsion Program, visit:

http://www.spacetransportation.com

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